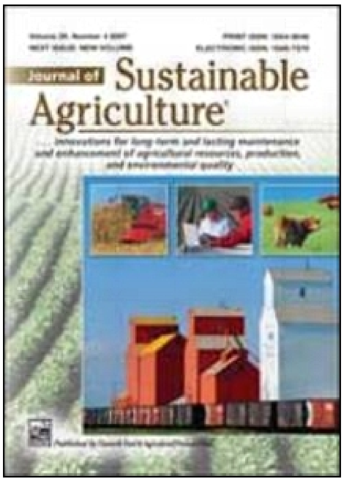

Journal of Sustainable Agriculture
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t792306915

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To cite this Article Huang, Wen-Yuan and Magleby, Richard(2003) 'The Economic Impacts of Restricting Agricultural Uses of Manure on Hog Farms in Southern Seaboard', Journal of Sustainable Agriculture, 23: 1, 31 — 57
To link to this Article: DOI: 10.1300/J064v23n01_04
URL: http://dx.doi.org/10.1300/J064v23n01_04

The Economic Impacts of Restricting Agricultural Uses of Manure on Hog Farms in Southern Seaboard

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ABSTRACT. EPA in December, 2000 proposed rules that would bring more livestock operations under regulation and restrict manure application more closely to crop nutrient needs. This paper, using individual whole-farm modeling applied to survey data, assessed the impacts of the proposed regulation on hog farms in the Southern Seaboard region. Results showed impacts would be particularly severe on large-size farms (over 2,500 pigs) applying manure to Bermuda hay. Feeding hogs a phytase diet that reduces phosphorous in manure reduced the income loss for farms with limited acres for applying manure.

KEYWORDS. Hog manure, land application restrictions, net return

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The authors would like to thank Darrell Bosch for useful suggestions made on an earlier draft. Responsibility for any errors or omission rests solely with the authors. The views expressed are those of the authors and do not necessarily represent the views of the Economic Research Service or the United States Department of Agriculture.

INTRODUCTION

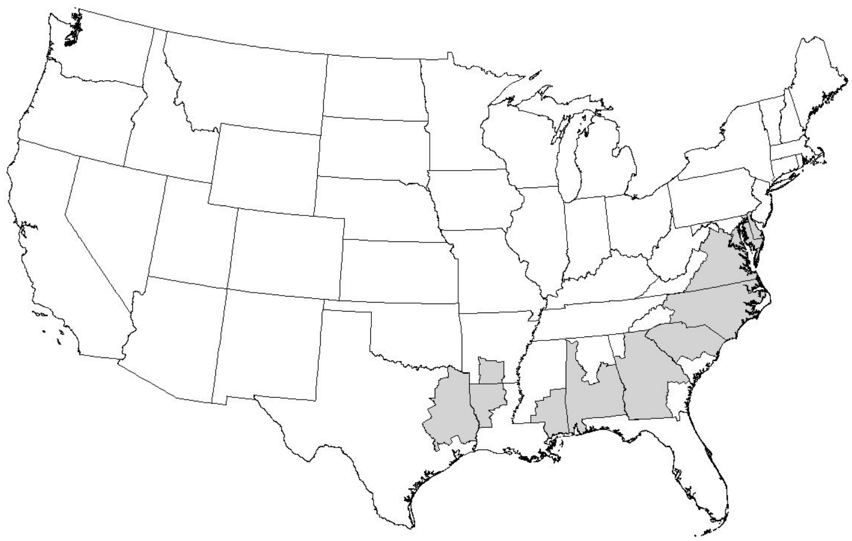
The environmental effects of concentrated livestock feeding operations and their associated waste management are an increasing source of public policy concern (Innes, 2000). In response, USDA and EPA have developed a Unified National Strategy for Animal Feeding Operations (AFOs) (USEPA, 1999). This strategy calls for all AFOs to implement Comprehensive Nutrient Management Plans (CNMP) to minimize the impact on water quality and public health. As part of this strategy, EPA in December, 2000 proposed several changes to current NPDES (National Pollutant Discharge Elimination System) permit regulations, and to current effluent guidelines (USEPA, 2000). The changes include redefining which concentrated animal feeding facilities (CAFOs) would be subject to the NPDES regulation, and specifying new effluent guidelines for an operation permit, including handling and land application of manure.

The most encompassing alternative that EPA is proposing for defining hog CAFOs is a three-tier structure which specifies a hog farm as a CAFO (1) if the number of hogs (weighing over 55 pounds) is over 2,500, or (2) if it has between 750 and 2,500 hogs and meets certain conditions, or (3) if it has fewer than 750 hogs and is specifically designated by the permit authority.[1] All facilities in the second group must either certify that they do not meet the conditions for being defined as a CAFO or must apply for a permit. This CAFO definition lowering the minimum number of hogs in a regulated facility from the current over 2,500 to over 750 hogs, will subject many more hog farms to regulation than currently.

EPA's proposed effluent guidelines would also affect both new and existing CAFOs. Under these guidelines, many CAFO operators may need to follow phosphorous (P)-based nutrient management plans (NRCS, 2001) rather than N-based plans as presently required. Under this plan, CAFOs would need to restrict manure application to the amount of P needed by crops, or restrict manure application to the amount of nitrogen (N) needed by crops in the areas of low P in the soil. These proposed changes in NPDES guidelines along with a new CAFO classification could increase hog production costs and reduce hog farm profits in the Southern Seaboard (SS) region (Figure 1).

The hog industry in the Southern Seaboard (SS) region in the past three decades has moved toward larger AFOs with limited cropland for manure disposal (McBride, 1995; McBride and Christensen, 2000). In 1998, the region contained 4,441 hog farms, about 7 percent of total

FIGURE 1. Southern Seaboard Farm Resource Region (shaded areas)



U.S. hog farms, and accounted for 19 percent of total U.S. hog sales. About 60 percent of all farms and 90 percent of large farms (>750 hogs) in the SS region were located in North Carolina (NC) in 1998. Many of the large farms in NC are located close to water bodies and on areas where soil and groundwater are vulnerable to nutrient pollution (North Carolina Department of Agriculture). Farms in North Carolina currently are required under State regulations to apply manure in quantities that meet but not exceed crop N use rates (Bosch et al., 1998). Changing to a P-restriction under the EPA's proposed rules would require more crop acres to dispose manure adequately (Bosch et al., 1998). Many farms in the SS region may not have adequate cropland to follow P-based nutrient management plans.

OBJECTIVE

This research assessed how the proposed EPA (2000) rule changes on CAFOs and manure application would affect hog operations and their profitability in the SS region. The research addressed the following questions: How many additional hog farms would be subject to the regulation? What percent of regulated farms would have to arrange for additional land to properly disperse manure and what acreage would be needed? What would be the cost (reduction in net crop returns) per farm and per hog sold to comply with regulation? What would be the marginal value to the farm to reduce the amount of manure on farm to comply with the regulation?

ADDITIONAL AFFECTED FARMS

The information base for this assessment was a national survey of hog operations conducted under the 1998 Agricultural Resource Management Study Phase III. A total of 404 farms in the SS region responded to the survey, representing 4,441 hog farms when expanded by survey weights (Table 1). A total of 2,140 farms or about 48 percent would be affected by the proposed rule changes. The current EPA regulation, which requires farms over 2,500 hogs at one time during a production year to have permits, affects 1042 hog farms or about 23 percent of the regional total. The new definition of CAFO, thus, would bring an additional 1,098 or about 25 percent of the region's hog farms under regulation. Of the total affected farms, 64 percent are feeder-pig-to-finish operations, and 11 percent are farrow-to-finish operations.

This study focused only on surveyed feeder-pig-to-finish farms, which were the largest group of hog operations in the region. The farms in this group were divided into subgroups according to their manure type, field application method, and crops grown (Table 2). In total, 16 subgroups of farms were identified, but only 3 subgroups that had ten surveyed farms or more were included in this analysis for reliability reasons (marked with an asterisk in the Table 2). These 3 subgroups were (1) large and (2) medium-size feeder-pig-to-finish farms spreading lagoon manure on hay, and (3) large feeder-pig-to-finish farms spreading lagoon liquid manure on corn-soybean-wheat. The three subgroups contained 69 surveyed hog farms in total.

ASSESSMENT MODELS

Following the analytical framework employed by Chase and Duffy (1991), an individual whole farm model was formulated from survey data for each of 69 selected farms, assuming the farm would maintain the same size of hog operation and same crop production practices under the proposed restrictions.

TABLE 1. Number of surveyed farms and estimated number of farms in the Southern Seaboard classified by the maximum hog capacity

Operation type	Number of surveyed farms	Number of farms estimated
Farrow-to-finish		
Hogs ≥ 2,500	16 (12%)	96 (7%)
2,500 > hogs ≥ 750	21 (16%)	138 (10%)
Hogs < 750	97 (72%)	1,205 (83%)
Subtotal	134 (100%)	1,439 (100%)
Farrow-to-feeder-pig		
Hogs ≥ 10,000	5 (12%)	47 (8%)
10,000 > hogs ≥ 3,000	9 (22%)	98 (17%)
Hogs < 3,000	27 (66%)	436 (75%)
Subtotal	41 (100%)	581 (100%)
Feeder-pig-to-finish		
Hogs ≥ 2,500	93 (63%)	946 (60%)
2,500 > hogs ≥ 750	35 (24%)	421 (27%)
Hogs < 750	19 (13%)	207 (13%)
Subtotal	147 (100%)	1,574 (100%)
Farrow-to-weaning		
Hogs ≥ 10,000	0 (0%)	0 (0%)
10,000 > hogs ≥ 3,000	4 (40%)	37 (32%)
Hogs < 3,000	6 (60%)	78 (68%)
Subtotal	10 (100%)	115 (100%)
Weaning-to-feeder-pig		
Hogs ≥ 10,000	0 (0%)	0 (0%)
10,000 > hogs ≥ 3,000	26 (76%)	248 (75%)
Hogs < 3,000	8 (24%)	81 (25%)
Subtotal	34 (100%)	329 (100%)
Mixed operations[1]		
Hogs ≥ 2,500	11 (29%)	80 (27%)
2,500 > hogs ≥ 750	5 (13%)	29 (10%)
Hogs < 750	22 (68%)	295 (63%)
Subtotal	38 (100%)	403 (100%)
Total	404	4,441
Total affected	225	2,140

[1]Operations that do not fit into any of the above categories. These operations may have more than one type of production activity.
Source: USDA, ERS, Based on 1998 Agricultural Resource Management Study survey.

TABLE 2. Number of surveyed farms that would be affected by EPA's proposed CAFO rule, Southern-Seaboard region

Type of operation[1]	Large farms (2,500 + hogs)	Medium farms (750-2,500 hogs)
Feeder-pig-to-finish operations	Number (% of subtotal)	
Slurry manure		
Spreading slurry on hay	1 (50%)	0 (0%)
Spreading slurry on csw	0 (0%)	0 (0%)
Spreading slurry on cs	1 (50%)	0 (0%)
Others	0 (0%)	1 (100%)
Subtotal	2 (100%)	1 (100%)
Lagoon liquid manure		
Spreading manure on hay	**40 (44%)***	**10 (29%)***
Spreading manure on csw	**19 (21%)***	2 (6%)
Spreading manure on cs	3 (3%)	2 (6%)
Others	29 (32%)	20 (59%)
Subtotal	91(100%)	34 (100%)
Farrow-to-finish operations		
Slurry manure		
Spreading slurry on hay	0 (0%)	0 (0%)
Spreading slurry on csw	0 (0%)	0 (0%)
Spreading slurry on cs	0 (0%)	0 (0%)
Others	0 (0%)	0 (0%)
Subtotal	0 (0%)	0 (0%)
Lagoon liquid manure		
Spreading manure on hay	4 (25%)	5 (24%)
Spreading manure on csw	2 (13%)	5 (24%)
Spreading manure on cs	3 (19%)	1 (5%)
Others	7 (57%)	10 (47%)
Subtotal	16 (100%)	21 (100%)
Total surveyed farms	109	56
Total analyzed	59 (54%)	10 (18%)

[1]Hay = Bermuda grass hay, Cs = Corn-soybeans rotation, Csw = Corn-soybeans-wheat rotation.
Others include farms growing minor crops, farms in type of operation groups with less than 5 farms, and farms with missing data.
*Ten or more farms.
Source: USDA, ERS data from 1998 Agricultural Resource Management Study survey of U.S. hog farms.

Objective Function. We assume that the hog farm operator, with current (1998) number of hogs and cropping systems, will maximize the net return, Z, from the crop production portion of the operation for crop *i* given the availability of manure produced on the farm and a given crop acreage operated by the farm on which manure can be applied.[2] The farm determines acres, C_{im}, to receive manure and acres, C_{in}, not to receive manure. The farm leases additional acres L_S for manure application if the farm owned acreage, L_o, is insufficient. The farm also determines the manure application rate, A_i, and the amount of nutrient j from commercial fertilizers for crop i, F_{ij}. The objective function that maximizes crop net return NR_m from manured acres and crop net return NR_n from non-manured acres is specified as

$$\text{Maximize } Z = NR_m + NR_n \tag{1}$$

Where $NR_m = \Sigma_i(p_i\, y_i - o_i)\, C_{im} - \Sigma_i\Sigma_j f_j\, F_{ij}\, C_{im} - MAC - r\, L_S$ and $NR_n = (\Sigma_i\, (p_i\, y_i - o_i - \Sigma_j f_j\, d_{ij}\, y_i)\, C_{in}$. p_i is the price ($/bushel) of crop i, y_i is the crop yield (bushel/acre), o_i is production costs other than fertilizer and land ownership costs ($/acre). f_j is the cost ($/pound) of j nutrient of commercial fertilizer, and d_{ij} is the pounds of j nutrient needed to produce one bushel (ton) of i crop, j = n (nitrogen), p (phosphate), k (potash); and *MAC* is the manure application cost ($) (to be defined later); and r is the land rent ($/acre) of leased acres for manure application. y_i is obtained from the survey. The objective function is subject to the following set of restrictions:

Acreage Restrictions

$$\Sigma_i(C_{im} + C_{in}) - L_s = L_o \tag{2}$$

where L_o is the farm owned tillable acres obtained from the survey.

Manure Use Restriction

$$\Sigma_i A_i C_{im} = m\, Hog \tag{3}$$

where *Hog* is the number of hogs on the farm, expressed in animal units, as obtained from the survey and held constant.

Per-Acre Nutrients Required by Crops

$$F_{ij} + u_j A_i + y_s - d_{ij} y_i \geq 0 \text{ for } i \text{ and } j \tag{4}$$

where u_j is the pounds of j nutrient in 1000 gallons of manure; and d_{ij} is the pounds of j nutrient needed to produce one bushel of crop i. This restriction requires that the applied amount of each nutrient per acre from commercial fertilizer and manure must meet the amount needed by the crop. y_s is N credit from soybeans in rotation with corn, assumed to be 1 pound of N fixed per bushel of soybeans harvested. y_s is set to zero for $j = p$ or k.

Nutrient Application Restrictions

$$F_{ij} + u_j A_i + y_s - d_{ij} y_i + S_{ij} \leq 0 \text{ for } i \text{ and } j \tag{5}$$

where S_{ij} is the amount of surplus manure nutrient j applied to crop i but not utilized by the crop and $S_{ij} > 0$. S_{ij} has no value to the farm. S_{ij} is set to zero when nutrient j is restricted. For example, S_{in} becomes zero when N is restricted. Surplus manure nutrients P can occur when the manure application rate is restricted based on N because one unit of manure supplies more P than N needed by the crop (such as hay or corn).

Manure Application Cost (MAC). To estimate manure application costs, a travel gun irrigation system was assumed. The cost of spreading lagoon liquid on the soil surface, \$/acre, was determined by the acres irrigated, annual gross rate of application for crop i (D_i in inches), and h pumping capacity. The manure application cost (*MAC*) is:

$$\text{MAC} = MAC(C_{im}, D_i, h) \tag{6}$$

Cox's formulation of (6) was used to estimate the manure application cost. The pumping capacity, h was assumed to be 2 hours per acre-inch for a large hog operation and 3 hours per acre-inch for a medium-sized farm. This implies that a large farm would require a larger pumping capacity than a medium-sized farm to minimize hours to spread the manure. The costs were inflated to 2000 dollars using the index of prices-paid-by-farmers (NASS).

TECHNICAL DATA AND ASSUMPTIONS

Crop yields, manured acres, total available crop acres, and number of hogs were used as parameters in formulating each of the 69 selected surveyed farm for the empirical research. Furthermore, the research performed in this study made several key assumptions.

1. All farms using a similar manure system were assumed to have the same technical coefficients for manure production, nutrients in manure, and nutrients required by crops. These coefficients were obtained from published and unpublished sources (Table 3). Manure from lagoons was assumed to be liquid. Manure from each farm was considered to be incorporated if more than 50 percent was incorporated, according to the survey. Otherwise it was assumed to be surface spread.
2. The operation maintained the same number of hogs, type of hog operation, and size of manure storage and application system regardless of the manure application restrictions.[3]
3. The operation leased additional land when needed to meet manure nutrient application restrictions, and cropped and harvested this land the same as existing land. Cash rent paid for additional land was $40 per acre (NASS, 2000).
4. Bermuda hay and a corn-soybeans-wheat rotation were the two major cropping patterns in the region, and the only ones included in the analysis. Yields of these crops as reported by the surveyed operator were used to determine the lower bound on the amounts of nutrients needed for crop growth. The potential yields of those crops (Zering et al., 1999), which were generally higher than the survey yields, were used to determine an upper bound on the amounts of nutrients needed from crop growth.[4] The same crop yields were assumed for both manured and non-manured but commercially fertilized acres.
5. Corn, soybeans, and wheat prices were the deficiency loan rates in 2000: $2.10/bu for corn, $5.34/bu for soybeans, and $2.47/bu for wheat in SS region (FAS, 2000). Price of hay was assumed to be $34/ton (Bosch et al., 1998). Fertilizer nutrient prices, which included application costs, were $0.27/lb for nitrogen, $0.31/lb for phosphate, and $0.17/lb for potash, based on April, 2000 USDA published prices except the nitrogen price was adjusted upward to reflect higher natural gas prices in April, 2001 (NASS, 2000). Crop production costs excluding fertilizer and land ownership costs were $276/ac for corn, $166/ac for soybeans, $144/ac for wheat, and $230/ac for hay (ERS, 2001 and NCSU, 2001).
6. Phytase-supplemented feed was assumed to reduce P in hog excretion by 27.75 percent at a cost of $0.31 per hog for the feeder-pig-to-finish (Bosch et al., 1998).

TABLE 3. Technical coefficients used in all individual whole farm models

Manure production per pig sold and per animal unit (AU) capacity (Zering et al.)[1]

	Liquid (lagoon) manure	
	per pig sold - gallons -	per AU capacity - 1000 gallons -
Feeder-pig-to-finish	326	6.84

Nutrient content of lagoon manure and amounts of nutrients needed by selected crops (Bosch et al.; Zering et al.; The Fertilizer Instate)

	Nutrient content of manure (u_j)		
	N	P_2O_5	K_2O
	--- Pounds/1,000 gallons ---		
	3	1.4	3.5
	Amounts of nutrient needed (d_{ij})[2]		
	N	P_2O_5	K_2O
Corn (lbs/bu)	1.2	0.37	0.27
Soybeans (lbs/bu)	3.75	0.92	1.38
Winter wheat (lbs/bu)	1.5	0.69	0.38
Hay (lbs/ton)	50	9.63	33.75

[1]We assume the average weight of pigs in the inventory for a feeder-pig-to-finish operation is 143 pounds with 3 production cycles per year. The lagoon liquid production for a feeder-pig-to-finish operation is from Bosch et al.
[2]These are the maximum amounts of nutrients that can be absorbed by crops. Soybeans have no need for N.

SCENARIOS AND INDICATORS

One baseline scenario and three restriction scenarios were specified for assessing the farm-level impacts:

Baseline: Manure application rate was unrestricted and manure was applied to the same number of acres reported by the surveyed farms. This simulated the actual land application of manure by surveyed farms in 1998.

N-restriction: Manure application was restricted to the nitrogen need of the individual crop, and acres receiving manure were restricted to the tillable land owned and leased by the farm.

P-restriction: Manure application was restricted to the phosphorous needs of an individual crop, and acres receiving manure were restricted to the tillable land owned and leased by the farm.

> *P-restriction/phytase diet:* Same as P-restriction but phytase added to hog feed to reduce the P content of manure and thus the land acres needed to dispose manure.

Four indicators were used to assess the farm-level impacts: (1) additional leased acres needed to comply with the restrictions, (2) net crop return to the farm, (3) net crop return per hog sold, (4) marginal cost of utilizing manure per 1000 gallons. Net crop return to a farm was gross crop return from both manured and non-manured acres of the farm less crop production and manure utilization costs. Marginal cost of utilizing manure was the reduction in net farm income from applying the last 1000 gallons of manure on the farm. The group average and the range (the maximum and minimum) are shown for each indicator. The economic impacts on the farm were the differences in these five indicators between the baseline and the restriction scenarios.

RESULTS OF THE ANALYSIS

Two sets of simulations were conducted to estimate the values of the indicators. The simulation results based on survey yields, which were lower than the potential yields, served as the lower-bound values of the indicators. The simulation results based on the potential yields served as the upper bounds of the indicators. Tables 4 to 6 show results of three (sub) groups of hog operations investigated. Each table summarizes the inputs used in the model, such as average animal units, acres owned, crop yields, and the results obtained from the models, such as average manure application rates, manured acres, purchased fertilizer, fertilizer cost, phytase costs, manure application costs, and land lease costs. These three tables also show the average costs to utilize manure and net return from crop production. The estimated costs and returns in this study were assumed in 1999-2000 dollars except crop prices.

Additional Leased Acres

By comparing the manure application rates between the baseline's and the restriction's, manure was applied to crops in excess of nutrient needs under the baseline scenario (Tables 4 to 6). More acres for spreading manure would be needed when the restriction was imposed. Under the restriction scenarios, we assumed that hog farm would lease additional land to utilize manure if current cropland was inadequate to comply with manure application restrictions. Another option would have been to assume that farms find other means to dispose of surplus manure. However, since the 1998 hog farm survey indicated that only a few (3 percent) CAFOs in the region paid for haul-off of manure from their operations and none had given or sold it, we decided to base our analysis on the leasing option.

TABLE 4. Average cost and returns to hay production on Southern Seaboard large feeder-pig-to-finish farms (2,500 + hogs) spreading lagoon liquid manure on the soil surface

A. Based on survey crop yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Number of farms	405			
Animal units /farm	1,351			
Acres owned/farm	113			
Own acres received manure/farm	66	81	100	97
Manured total acres/farm	70	177	431	311
Hay yield (tons/ac)	4.03	4.03	4.03	4.03
Manure application rate for hay (1000 gal/ac)	177	67	28	38
Manure N (lb/acre)	531	201	84	114
Manure P_2O_5 (lb/acre)	247	94	39	53
Manure K_2O (lb/acre)	619	235	98	133
Commercial N (lb/acre)	23	0.60	112	67
Commercial P_2O_5 (lb/acre)	0.33	0	0	0
Commercial K_2O (lb/acre)	6.32	0	30	1.18
Commercial fertilizer cost ($/farm)	494	16	12,866	5,663
Phytase cost ($/farm)	0	0	0	8,785
Manure application costs ($/farm)	9,877	12,765	23,104	18,056
Land lease cost/farm ($/farm)	140	3,865	13,252	8,560
Manure utilization costs ($/farm)	10,511	16,645	49,210	41,064
Fertilizer value of manure/farm ($)	5,991	12,336	17,000	15,883
Net cost to utilize manure ($/farm)[1]	4,520	4,311	32,222	25,181
Crop returns ($/farm)	9,923	18,898	45,694	32,965
Other costs ($/farm)	15,306	40,966	96,045	71,563
Net crop returns ($/farm)[2]	−15,894	−38,714	−99,561	−79,662
Maximum	−4,292	−1,799	−7,397	−10,316
Minimum	−27,446	−176,038	−440,226	−323,575

B. Based on potential crop yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Own acres received manure/farm	66	79	100	98
Manured acres/farm	70	102	247	180
Hay yield (tons/ac)	4.03	5.45	5.45	5.45
Manure application rate for hay (1000 gal/ac)	177	90	37	52
Manure N (lb/acre)	531	270	111	156
Manure P_2O_5 (lb/acre)	247	126	52	38
Manure K_2O (lb/acre)	619	315	129	182
Commercial N (lb/acre)	23	0.57	159	117
Commercial P_2O_5 (lb/acre)	0.33	0	0	0
Commercial K_2O (lb/acre)	6.32	0	53	2
Commercial fertilizer cost ($/farm)	494	16	12,866	5,663
Phytase cost ($/farm)	0	0	0	8,785
Manure application costs ($/farm)	9,877	9,892	15,281	12,531
Land lease cost/farm ($/farm)	140	927	5,913	3,284
Manure utilization costs ($/farm)	10,511	10,835	34,060	30,263
Fertilizer value of manure/farm ($)	5,991	12,336	17,000	15,882
Net cost to utilize manure ($/farm)[1]	4,520	(1,501)	17,060	14,381
Crop returns ($/farm)	9,923	18,898	45,694	32,965
Other costs ($/farm)	15,306	23,558	57,015	41,132
Net crop returns ($/farm)[2]	−15,894	−15,495	−45,381	−38,430
Maximum	−4,292	−1,799	−7,397	−10,315
Minimum	−27,446	−29,178	−89,163	−73,346

[1]Net cost to utilize manure = cost to utilize manure − fertilizer value of manure.
[2]Net crop return = crop returns − other costs − manure utilization costs. Price of hay is $34/ton (Bosch et al.). Other cost is $230/ac, which is the total production cost excluding fertilizer cost and land rent (NC budget). Fertilizer prices are $0.27/lb, $0.31/lb, and $0.17/lb for N, P_2O_5, and K_2O fertilizers, respectively.
Sources: Results of individual whole farm modeling.

With restrictions on application of N or P in manure, most farms would have to lease additional acres to utilize manure (Table 7). The P-restriction in particular had a large impact on feeder-pig-to-finish operations spreading manure on hay. Under this restriction, 93 percent of the large farms in this type of operation needed to lease additional acres for spreading manure, if survey crop yields were used to determine the maximum amount of P nutrient needed by hay. The average additional acreage needed was 331 acres. Farms could reduce leased acres by improving hay yield. The average leased acres could be reduced from 331

TABLE 5. Average costs and returns to a corn-soybean-wheat rotation on Southern Seaboard large feeder-pig-to-finish farms (2,500 + hogs) spreading lagoon liquid manure on the soil surface

A. Based on survey crop yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Number of farms	157			
Animal units/farm	1,074			
Acres owned/farm	453			
Own acres received manure/farm	69	289	346	276
Manured total acres	69	396	516	376
Corn yield (bu/ac)	52	58	58	58
Wheat yield (bu/ac)	34	34	34	34
Soybeans yield (bu/ac)	27	27	27	27
Manure application rate for corn (1000 gals/ac)	98	14	15	21
Manure application rate for wheat (1000 gals/ac)	136	33	17	23
Manure application rate for soybeans (1000 gals/ac)	102	17	18	24
Manure N (lb/ac)[1]	336	64	50	68
Manure P_2O_5 (lb/ac)	157	30	23	32
Manure K_2O (lb/ac)	392	75	58	79
Commercial N (lb/ac)	0	0	1	0
Commercial P_2O_5 (lb/ac)	0	0	0	0
Commercial K_2O (lb/ac)	0	0	0	0
Commercial fertilizer cost ($/farm)	0	0	139	0
Phytase cost ($/farm)	0	0	0	7,310
Manure application costs ($/farm)	12,953	22,224	27,214	21,438
Land lease cost ($/farm)	0	4,280	6,800	4,000
Manure utilization costs ($/farm)	12,953	26,504	34,153	32,748
Fertilizer value of manure ($/farm)	1,074	6,113	8,815	5,434
Net cost to utilize manure ($/farm)[2]	10,802	20,391	25,388	27,314
Crop returns ($/farm)	7,750	41,520	54,127	39,436
Other costs ($/farm)	12,953	73,334	95,696	69,722
Net crop returns ($/farm)[3]	−18,156	−58,318	−75,722	−63,034
Maximum	−13,132	−4,117	−24,312	−22,110
Minimum	−27,446	−81,661	−106,014	−85,717

B. Based on potential crop yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Own acres received manure/farm	69	183	224	177
Manured total acres/farm	69	205	468	196
Corn yield (bu/ac)	52	120	120	120
Wheat yield (bu/ac)	34	55	55	55
Soybeans yield (bu/ac)	27	35	35	35
Manure application rate for corn (1000 gals/ac)	98	36	32	43
Manure application rate for wheat (1000 gals/ac)	136	27	27	37
Manure application rate for soybeans (1000 gals/ac)	102	44	23	32
Manure N (lb/ac)[1]	336	107	82	112
Manure P_2O_5 (lb/ac)	157	50	38	46
Manure K_2O (lb/ac)	392	125	96	130
Commercial N (lb/ac)	0	0	5	0
Commercial P_2O_5 (lb/ac)	0	0	0	0
Commercial K_2O (lb/ac)	0	0	0	0
Commercial fertilizer cost ($/farm)	0	0	365	0
Phytase cost ($/farm)	0	0	0	6,983
Manure application costs ($/farm)	12,953	14,674	17,022	14,384
Land lease cost ($/farm)	0	892	1,833	780
Manure utilization costs ($/farm)	12,953	15,566	19,220	22,147
Fertilizer value of manure ($/farm)	1,074	8,104	10,151	6,801
Net cost to utilize manure ($/farm)[2]	10,802	−7,462	−9,069	−15,346
Crop returns ($/farm)	7,750	39,260	51,621	37,609
Other costs ($/farm)	12,953	37,979	49,937	36,382
Net crop returns ($/farm)[3]	−18,156	−14,285	−17,536	−20,920
Maximum	−13,132	−8,430	−8,940	−10,859
Minimum	−36,192	−28,963	−41,345	−44,200

[1]The average of three crops.
[2]Net cost to utilize manure = manure utilization costs − fertilizer value of manure.
[3]Net crop return = crop returns − other costs − manure utilization costs. Prices of corn, wheat, and soybeans are $2.10/bu, $2.47/bu, and $5.34/bu (2001 loan rates). Other costs for corn is $276/ac, for soybean $166/ac, and for wheat $114/ac (ERS Website). The other cost is the total production cost excluding fertilizer cost and land rent. Fertilizer prices are $0.27/lb, $0.31/lb, and $0.17/lb for N, P_2O_5, and K_2O fertilizers, respectively. These data are the averages of April prices of 1998 and 1999 (NASS).
Sources: Results of individual whole farm modeling.

to 147 acres if the potential hay yield level was achieved. The P-restriction had less impact on feeder-pig-to-finish operation spreading manure on corn, soybean, and wheat. Most farms (60%) had adequate land for spreading manure on these crops. Feeding hogs a phytase additive effectively reduced the additional acreage needed by the hog farms.

TABLE 6. Average costs and returns to hay production on Southern Seaboard medium feeder-pig-to-finish farms (750-2,500 hogs) spreading lagoon liquid manure on the soil surface

A. Based on survey yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Number of farms	156			
Animal units /farm	403			
Acres owned /farm	42			
Own acres received manure/farm	18	32	38	36
Manured total acres /farm	18	75	182	131
Hay yield (tons/ac)	3.52	3.52	3.52	3.52
Manure application rate for hay (1000 gal/ac)	160	59	24	34
Manure N (lb/ac)	480	177	72	102
Manure P_2O_5 (lb/ac)	224	83	72	48
Manure K_2O (lb/ac)	560	206	133	119
Commercial N (lb/ac)	0	0	162	118
Commercial P_2O_5 (lb/ac)	0	0	0	0
Commercial K_2O (lb/ac)	0	0	0	2
Commercial fertilizer cost ($/farm)	0	0	3,841	1,690
Phytase cost ($/farm)	0	0	0	2,623
Manure application costs ($/farm)	6,080	6,747	10,788	8,745
Land lease cost ($/farm)	0	1,720	5,760	3,800
Manure utilization cost ($/farm)	6,080	8,467	20,389	16,858
Fertilizer value of manure ($/farm)	3,618	3,680	5,075	4,741
Net cost to utilize manure ($/farm)[1]	2,462	4,787	15,314	12,177
Crop returns	1,965	5,630	13,641	9,841
Other costs	4,085	17,278	41,865	30,202
Net crop returns ($/farm)[2]	−8,200	−20,115	−48,613	−37,219
Maximum	−5,629	−5,190	−7,449	−7,320
Minimum	−10,137	−43,121	−105,001	−77,655

B. Based on potential crop yields to determine crop's need for manure

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Own acres received manure/farm	18	25	38	35
Manured total acres/farm	18	30	73	52
Hay yield (tons/ac)	3.52	5.56	5.56	5.56
Manure application rate for hay (1000 gal/ac)	160	93	38	52
Manure N (lb/ac)	480	277	115	159
Manure P_2O_5 (lb/ac)	224	130	53	56
Manure K_2O (lb/ac)	560	325	133	182
Commercial N (lb/ac)	0	0	162	118
Commercial P_2O_5 (lb/ac)	0	0	0	0
Commercial K_2O (lb/ac)	0	0	0	2
Commercial fertilizer cost ($/farm)	0	0	3,840	1,690
Phytase cost ($/farm)	0	0	0	2,622
Manure application costs ($/farm)	6,080	5,398	6,276	5,660
Land lease cost ($/farm)	0	213	1,403	694
Manure utilization cost ($/farm)	6,080	5,611	11,519	10,666
Fertilizer value of manure ($/farm)	3,618	3,679	5,075	4,741
Net cost to utilize manure ($/farm)[1]	2,462	1,932	6,444	5,925
Crop returns	1,965	5,630	13,641	9,841
Other costs	4,085	6,904	16,735	12,072
Net crop returns ($/farm)[2]	−8,200	−6,885	−14,613	−12,897
Maximum	−5,629	−5,190	−7,449	−7,320
Minimum	−10,137	−8,474	−19,008	−16,361

[1]Net cost to utilize manure = manure utilization costs − fertilizer value of manure.
[2]Net crop return = crop returns − other costs − manure utilization costs. Price of hay is $34/ton (about half of NASS reported price). Other cost is $230/ac, which is the total production cost excluding fertilizer cost and land rent (NC budget). Fertilizer prices are $0.27/lb, $0.31/lb, and $0.17/lb for N, P_2O_5, and K_2O fertilizers, respectively.
Sources: Results of individual whole farm modeling.

Will the farms be able to lease additional land to dispose surplus manure? The possibility in some areas of the region is limited. Most counties in the North Carolina Seaboard where CAFOs are located had excess manure phosphorous (Kellogg et al., 2000). Under the proposed restrictions, these counties would not have enough cropland to assimilate the excess phosphorous and would have to export manure to other counties. Because the cost of hauling liquid manure off the farms ($5 for base charge per 1000 gallons and $3 per mile per 1000 gallons,

TABLE 7. Additional leased acres needed by farms in Southern Seaboard to comply with restrictions on land application of manure for crop production, feeder-pig-to-finish operations

	N-restriction	P-restriction	P-restriction with phytase
Based on survey crop yields to determine crop's need for manure			
Operation type and size group	Acres/farm (percent of surveyed farms in group)[1]		
Large-spreading-manure on hay			
Average[2]	97 (80%)	331 (93%)	214 (85%)
Maximum	537	1,431	1,007
Minimum	0	0	0
Large-spreading-manure on csw[3]			
Average	107 (40%)	170 (40%)	100 (40%)
Maximum	997	1,466	254
Minimum	0	0	0
Medium-spreading-manure on hay			
Average	43 (78%)	144 (89%)	95 (78%)
Maximum	127	337	237
Minimum	0	0	0
Based on potential crop yields to determine crop's need for manure			
Operation type and size group	Acres/farm (percent of surveyed farms in group)[1]		
Large-spreading-manure on hay			
Average[2]	23 (64%)	147 (92%)	82 (81%)
Maximum	116	412	253
Minimum	0	0	0
Large-spreading-manure on csw[3]			
Average	22 (28%)	46 (33%)	19 (28%)
Maximum	0	481	254
Minimum	0	0	0
Medium-spreading-manure on hay			
Average	5 (44%)	35 (88%)	17 (66%)
Maximum	21	71	47
Minimum	0	0	0

[1]Percent of farms in the group needing to lease additional land.
[2]Averages are weighted using survey weights.
[3]Csw = corn-soybeans-wheat rotation.
Source: Results of individual whole farm modeling.

(Fleming et al., 1998) far exceeds the fertilizer value of manure (less than $2 per 1000 gallons), hauling manure out of the region would not be economical. Using or developing alternative on-farm technologies to reduce surplus P in the liquid manure could be more economical for the farms in the region. Possible on-farm technologies include hog diets (similar to phytase) that reduce P in animal excretion, and biological, physical, and chemical filters that remove excess P in manure before field applications (NCSU, 2000).

Average Net Crop Returns per Farm and per Hog Sold

All survey farms in the three operational groups (Tables 4-6) in the region had negative crop returns in 1998 (the baseline scenario) mainly due to manure application costs, low crop yields, low crop prices, and high production costs. Under the baseline scenario, large feeder-pig-to-finish farms in the first group (spreading manure on hay) (Table 4. A), on average lost $15,894, with maximum loss $27,446 and minimum loss $4,292. The loss increased to $38,714 (by more than 100 percent) under the N-restriction scenario, to $99,561 (by more than 600 percent) under the P-restriction scenario and to $79,662 under the P-restriction with phytase feed. The losses would be reduced by more than half if the farms achieved the potential hay yields instead of the survey yields (Table 4. B). Phytase reduced losses when farms with limited cropland had to comply with the P-restriction.

Similar income losses also were estimated for the farms in the other two operational groups (Tables 5 and 6). Farms in these two groups had smaller (but still substantial) income losses (net crop returns per farm) than the farms in the first group. Large feeder-pig-to-finish farms in the second group spreading manure on corn-soybeans-wheat lost $18,156 on average under the baseline scenario (Table 5). The average loss increased to $58,318 under the N-restriction, and to $75,722 under the P-restriction. Achieving potential crop yields reduced the losses to $14,285 under the N-restriction and to $17,536 under the P-restriction. Use of phytase increased income loss under the P-restriction, indicating that many farms in this group had sufficient acres for manure application, and that the added cost of phytase and reduced fertilizer value of P in manure exceeded the cost saving from reduced manure application. Also, under the P-restriction, large farms spreading manure on corn-soybean-wheat had a smaller income loss per manured acre than large farms in spreading manure on hay mainly because of fewer leased acres due to smaller hog-land ratios, larger gross net returns from crops, and less cost for supplemental N fertilizer for crop need.

Medium-size feeder-pig-to-finish farms in the third group spreading manure on hay lost $8,200 on average under the baseline scenario (Table 6). The average loss increased to $20,115 under the N-restriction scenario, and to $48,613 under the P-restriction scenario. If the farms could achieve potential yield levels, average loss would be significantly reduced to $6,885 under the N-restriction, and to $14,613 under the P-restriction. Use of phytase reduced the income loss when the farms must comply with the P-restriction scenario. Farms in this group on average also had smaller income losses per manured acre than the farms in the first group, mainly due to smaller hog-land ratios.

Further study based on potential yields showed that large feeder-pig-to-finish farms spreading manure on hay would be able to reduce the costs of complying with the P-restriction by changing to a corn-soybeans-wheat rotation. The latter had higher crop gross net return per acre (crop gross return less production costs) and also required less additional commercial N fertilizer per acre than hay in complying with the P-restriction. Under the P-restriction, the farms must purchase additional N fertilizer to supply N for the hay's need because the N-P ratio of nutrients (about 2) in the manure is much smaller than the N-P ratio of nutrients (about 5) needed by the hay.

Net crop return (loss) per hog sold is an important piece of information that can help the farm operator determine how much crop income loss he or she has to absorb (or add) for each hog sold. Under the baseline scenario, the average loss was less than $1 for the large feeder-pig-to-finish farms in the first and the second groups and around $1 for the medium-size farms in the third groups (Table 8). The net returns per hog sold for large farms in the first group averaged slightly smaller than the net returns per hog sold for medium size farms in the third group. Net returns per hog sold for the large operation are comparable with the estimates by Bosch et al. (1998).

The proposed restrictions caused large crop income losses per hog sold for farms in all three groups when survey yields were used to determine crops' need for manure. However, crop income loss per hog sold on the medium-size farms (the third group) was greater than on the large farms. Farms in this medium size group had crop income losses increase more than 100 percent under the N-restriction, more than 400 percent under the P-restriction, and more than 300 percent under the P-restriction with phytase diet. Farms in all three groups could reduce the in-

TABLE 8. Net (crop) return per hog sold under various manure application scenarios, Southern Seaboard feeder-pig-to-finish farms

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Based on survey crop yields to determine crop's need for manure				
Operation type and size group	$/hog sold (percent of surveyed farms in group)[1]			
Large-spreading-manure on hay				
Average[2]	−0.71 (100%)	−1.56 (100%)	−3.98 (100%)	−3.11 (100%)
Maximum	−0.08	−0.09	−0.68	−0.61
Minimum	−3.31	−5.56	−13.79	−10.15
Large-spreading-manure on csw[3]				
Average	−0.93 (100%)	−2.23 (100%)	−2.86 (100%)	−2.43 (100%)
Maximum	−1.85	−0.95	−1.25	−1.23
Minimum	−10.58	−4.82	−6.58	−5.02
Medium-spreading-manure on hay				
Average	−1.03 (100%)	−2.52 (100%)	−6.03 (100%)	−4.61 (100%)
Maximum	−0.54	−0.42	−0.91	−0.93
Minimum	−1.38	−5.72	−13.94	−10.31
Based on potential crop yields to determine crop's need for manure				
Operation type and size group	$/hog sold (percent of surveyed farms in group)[1]			
Large-spreading-manure on hay				
Average[2]	−0.71 (100%)	−0.62 (100%)	−1.70 (100%)	−1.44 (100%)
Maximum	−0.08	−0.09	−0.43	−0.61
Minimum	−3.31	−0.98	−2.14	−1.84
Large-spreading-manure on csw[3]				
Average	−0.93 (100%)	−0.70 (100%)	−0.82 (100%)	−0.99 (100%)
Maximum	−0.58	−0.53	−0.64	−0.81
Minimum	−1.85	−1.06	−1.25	−1.37
Medium-spreading-manure on hay				
Average	−1.03 (100%)	−0.86 (100%)	−1.78 (100%)	−1.57 (100%)
Maximum	−0.54	−0.43	−0.91	−0.93
Minimum	−1.38	−1.21	−2.11	−1.82

[1]Porcent of farms in the group that had a negative net income.
[2]Averages are weighted using survey weights.
[3]Cs = corn-soybeans rotation, csw = corn-soybeans-wheat rotation.
Source: Results of individual whole farm modeling.

come losses by more than one-half if they achieved potential crop yields as opposed to survey yields.

Marginal Costs (Shadow Prices) of Manure

Information on the marginal cost (shadow price of the manure restriction) to the farm of utilizing the last 1000 gallons of manure could help the operator determine whether to expand or to reduce the number of hogs. It also could help the operator assess the economic feasibility of adopting alternative waste management technologies. A large positive marginal cost implies that the operator might be able to reduce the cost either by reducing the number of hogs on the farm, or by moving manure off the farm. A large negative marginal cost implies the farmer could improve net income by acquiring additional manure for crop production, either from expanding the hog operation or purchasing manure from other farms.

Most farms in 1998 had a positive marginal cost of manure use (Table 9), while a few farms had a negative marginal cost. The negative marginal cost occurred to the farms having had high crop yields and purchased supplemental commercial fertilizers for crop needs. Under the baseline scenario, about 92 percent of farms in the first group and all farms in the other two groups had positive marginal costs. The average marginal cost was \$0.33 for the last 1000 gallons for the farms in the first group, \$0.95 for the farms in the second group, and \$1.09 for the farms in the third group. Marginal costs increased substantially under the N and P restrictions. For example, for the farms in the first group, marginal cost increased from \$0.33 to \$4.34 under the N-restriction, to \$12.13 under the P-restriction, and to \$8.32 under the P-restriction with phytase diet. Similar large increases also occurred for the farms in the second and third group. Use of phytase reduced the marginal costs under the P-restriction, but the costs were still substantial. Farms could reduce average marginal costs by more than half by achieving potential crop yields instead of survey yields.

SUMMARY AND CONCLUSIONS

In response to public concerns about the environmental effects of large concentrated livestock feeding operations and their associated waste management, EPA (2000) has proposed several changes to current permit regulations. The changes include redefining concentrated

TABLE 9. Marginal costs of manure (shadow prices) under various application scenarios, Southern Seaboard feeder-pig-to-finish farms

	Baseline	N-restriction	P-restriction	P-restriction with phytase
Based on survey crop yields to determine crop's need for manure				
Operation type and size group	$/1000 gallons (percent of surveyed farms in group)[1]			
Large-spreading-manure on hay				
Average[2]	0.33 (92%)	4.34 (95%)	12.13 (100%)	8.32 (97%)
Maximum	3.60	16.78	42.04	29.94
Minimum	−1.70[3]	−0.34[5]	0.43	−0.08
Large-spreading-manure on csw[4]				
Average	0.95 (100%)	6.41 (100%)	8.51 (100%)	6.08 (100%)
Maximum	2.17	15.37	20.64	15.04
Minimum	0.43	2.88	3.86	2.79
Medium-spreading-manure on hay				
Average	1.09 (100%)	6.73 (100%)	17.84 (100%)	12.38 (100%)
Maximum	1.81	16.78	42.04	3.63
Minimum	0.72	0.31	2.15	1.16
Based on potential crop yields to determine crop's need for manure				
Operation type and size group	$/1000 gallons (percent of surveyed farms in group)[1]			
Large-spreading-manure on hay				
Average[2]	0.33 (92%)	1.34 (95%)	4.98 (100%)	3.14 (97%)
Maximum	3.61	1.72	5.57	3.63
Minimum	−1.70[3]	−0.34[5]	0.43	(0.08)
Large-spreading-manure on csw[4]				
Average	0.95 (100%)	1.33 (100%)	1.89 (100%)	1.28 (100%)
Maximum	2.17	2.16	2.89	2.07
Minimum	0.43	1.04	1.42	1.00
Medium-spreading-manure on hay				
Average	1.09 (100%)	1.16 (100%)	4.72 (100%)	2.84 (100%)
Maximum	1.81	1.72	5.57	3.63
Minimum	0.72	0.31	2.15	1.16

[1]Percent of farms in the group that could improve net return by reducing one 1000 gallons of manure produced on farm.
[2]Averages are weighted using survey weights.
[3]A negative value indicates the increase of crop net return from the last 1000-gallons applied.
[4]Csw = corn-soybeans-wheat rotation.
[5]This particular farm had not enough manure for producing 10 tons/acre of hay.
Source: Results of individual whole farm modeling.

animal feeding operations (CAFOs), and specifying new permit requirements for land application of CAFO manure. These changes would increase the number of hog farms subject to regulations and impose more restrictions on land application of manure than currently. This study assessed the economic impacts of these changes on hog farms in the Southern Seaboard (SS) region. Findings of this study are given below.

In our simulation analysis, all hog farms in the SS region in 1998 lost income from utilizing manure for crop production because of manure application costs and crop production losses. Most farms spread a large volume of lagoon liquid on the field, supplying manure nutrients exceeding the crops' needs. As a result, the cost of spreading manure was larger than the value of manure nutrients to the crops. This result is consistent with an earlier study by Roka and Hoag (1996). Also, most farms experienced low crop yields and crop prices in 1998. As a result, most farms experienced losses in net crop return because their crop production costs were larger than their crop returns.

EPA's proposal to restrict land application of manure to the nutrient need of receiving crops could further increase hog production costs for most hog operations in the SS. Our results suggest that most hog farms would have to increase the crop acreage receiving manure and absorb additional manure application costs. They also would have to absorb additional losses in net crop return from the expanded manured acres. Impacts would be particularly severe on large-size farms (over 2,500 pigs) applying manure to Bermuda hay. Most farms in the region could reduce their losses by feeding hogs a phytase diet that reduces phosphorous in manure, but the losses would still be substantial. Most farms might be able to reduce the income losses by switching to other crop production in place of Bermuda hay.

Most farms in the SS region could reduce the costs of complying with the N- or P-restrictions and minimize nutrient losses to the environment by improving their low crop yields. Higher crop yields could increase net crop returns on most farms. Higher crop yields would also take up more manure nutrients on the field and reduce residual nutrients on the field that might be lost to the environment. Higher crop prices and increased market demand for crops could provide farms the incentive to achieve higher crop yields.

Some farms in the region could face difficulty in finding additional cropland nearby to comply with the P-restriction, and face high costs to export manure to other counties. Alternative on-farm technologies to reduce P in the manure may be lower cost and are being researched in the region (NCSU, 2000).

In the absence of available new technologies, these farms would have to reduce the number of hogs in the operation to reduce manure production in order to comply with the proposed land application restrictions. As hog numbers reduced, the average cost of raising one hog increase because of under-utilization of their current production facilities. The high cost could make hog production unprofitable if the income from hog sales could not cover the cost.

Changes in the assumptions used in this analysis may affect the reported results. For example, a lower level of nutrient content in manure (than the level assumed in this study) would reduce the number of additional acres needed for manure application, and therefore reduce net income losses. Higher commercial fertilizer prices would improve the fertilizer value of the manure and therefore improve the net crop return from manured acres. Also higher crop prices would improve crop net return per farm. However, changes in these assumptions may not alter our conclusions that the P-based restriction could have a large negative economic impact on hog operations in the SS region, particularly on those large feeder-pig-to-finish farms currently applying hog manure to Bermuda hay.

NOTES

1. The proposed rule also includes farms producing immature hogs (weighing less than 55 pounds). For example, a farrow-to-feeder-pig farm is considered as a CAFO if the farm has over 3,000 hogs. Hog farms with fewer than 750 hogs are also considered as CAFO if their operations pose a threat to the environment. These farms were not included in this study because the information needed to identify these farms was not available from the survey. Furthermore, there are some changes in the proposed rules recently. The second group may no longer be in the latest proposed rule.

2. Number of hogs was held constant and the choice of crops was held fixed for each farm across the scenarios in order to focus on short-term effects. Many farms in the region are contracted operators and do not solely determine the number of pigs in their operations. Choice of crops is based on type of crops planted by the farm surveyed.

3. Increasing the size of storage in response to a restriction would increase cost more than expanding the land application (Boland, Preckel and Foster, 1998). Reducing the number of hogs to reduce surplus manure would be more costly to the farms than expanding land applications of manure (Roka and Hoag, 1996).

4. It is assumed that potential yields reported by Zering et al. would be closer to the realistic yields used by the hog farms in developing their nutrient management plan for

the hog operation. Most yields reported in the survey were lower than the potential (realistic) yields. One factor contributing for low yields could be due to the over-application of manure in the past that resulted in salt buildup in the soil, which could cause low yields.

5. A small number of large farms in 1998 may have used a phytase diet in their operations. This study assumed that the farms used no phytase. Removal of this assumption would not affect additional acres needed by the farms.

REFERENCES

Boland, M.A., P.V. Preckel, and K.A. Foster. "Economic Analysis of Phosphorus-Reducing Technologies in Pork Production." *Journal of Agricultural and Resources Economics* 23(2):468-482. 1998.

Boland, M.A., K.A. Foster, P.V. Preckel, D.D. Jones, and B.C. Joern. "Using Linear Programming to Minimize Manure Storage and Application Costs in Pork Production." *Journal of Production Agriculture*, 12(3):405-408, 1999.

Bosch, D.J., M. Zhu, and E.T. Kornegay. "Net Returns from Microbial Phytase When Crop Applications of Swine Manure Are Limited by Phosphorus," *Journal of Production Agriculture* 11(2):205-213, 1998.

Cox, V.N. A Cost Analysis of Irrigating Swine Waste Effluent. M.S. Thesis. North Carolina State Univ. Dep. of Agric. and Resource Economics, Raleigh, 1993.

Chase, C. and M. Duffy. "An Economic Comparison of Conventional and Reduced-Chemical Farming Systems in Iowa." *American Journal of Alternative Agriculture*. 64:168-174, 1991.

Economic Research Service, Costs and Return: Crops. http//www.ers.usda.gov/data/costs and returns. Accessed 3/10/2001.

Farm Service Agency. Price support programs 2000. *http://www.fsa.usda.gov/dafp/psd/loanrate.htm*. Accessed 3/10/2001.

Innes, R. "The Economics of Livestock Waste and Its Regulation." *American Journal of Agricultural Economics* 82: 97-117, 2000.

McBride, W. *U.S. Hog Production Costs and Returns, 1992: An Economic Basebook*. Agricultural Economic Report No. 724. Economic Research Service, U.S. Department of Agriculture. Nov. 1995.

National Agricultural Statistical Service (NASS). U.S. Department of Agriculture. *Agricultural Cash Rents*. Sp Sy 3(99). July 2000.

National Agricultural Statistical Service (NASS). U.S. Department of Agriculture. *Agricultural Input Prices*. April 2000.

Natural Resources Conservation Service, *Comprehensive Nutrient Management Planning: Technical Guidance*. U.S. Department of Agriculture, December 1, 2001.

North Carolina Department of Agriculture. *1995 Soil Summary*. North Carolina Department of Agricultural Soil Testing Division. Raleigh. 1996.

North Carolina State University (NCSU). *1999 Crop Budgets*. Department of Agricultural and Resource Economics, 2001.

North Carolina State University (NCSU). *Waste Management Programs*. Animal and Poultry Waste Management Center. October 2000.
Roka, F.M., and D.L. Hoag. "Manure Value and Liveweight Swine Decisions." *Journal of Agricultural and Applied. Economics* 28: 13-202, 1996.
The Fertilizer Institute. *The Fertilizer Handbook*. The Fertilizer Institute, Washington, DC 1982.
U.S. Environmental Protection Agency (USEPA). *U.S. Department of Agriculture and U.S. Environmental Protection Agency Unified National Strategy for Animal Feeding Operations*. Office of Wastewater Management, EPA, March 9, 1999.
U.S. Environmental Protection Agency (USEPA). *Concentrated Animal Feeding Operation Proposed Rule*. Office of Water, Engineering and Analysis Division, EPA. EPA 833-F-00-016, December 2000.
U.S. Department of Agriculture. National Agricultural Statistics Service. Hog Production Practices and Costs and Returns Survey, 1998.
U.S. Department of Agriculture. *USDA Agricultural Baseline Projections to 2010*. Office of the Chief Economist, Staff Report WABO-2000-1, Washington, DC, February 2000.
Weisz, R., E.J. Dunphy, and R.W. Heiniger. *Crop Budgets*. Department of Agricultural and Resource Economics, North Carolina State University. January 1998.
Zering K., K. Nelson, and T. Crawford. *An Economic Analysis of Swine Waste Management Systems for Selected States*, draft, Economic Research Service. U.S. Department of Agriculture. 1999.

RECEIVED: 04/30/02
REVISED: 08/23/02
ACCEPTED: 09/15/02